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RESEARCH ANNOUNCEMENT

Fundamental Physics in Microgravity: Research and Flight Experiment Opportunities

Letters of Intent Due: .... March 13, 2000

Proposals Due: .... May 15, 2000

OMB Approval No. 2700-0087

FUNDAMENTAL PHYSICS IN MICROGRAVITY: RESEARCH AND FLIGHT EXPERIMENT OPPORTUNITIES

NASA Research Announcement
Soliciting Research Proposals
for the Period Ending
May 15, 2000

NRA-00-HEDS-02
Issued: February 15, 2000

Office of Life and Microgravity Sciences and Applications
Human Exploration and Development of Space (HEDS) Enterprise
National Aeronautics and Space Administration
Washington, D.C. 20546-0001

NASA RESEARCH ANNOUNCEMENT
FUNDAMENTAL PHYSICS IN MICROGRAVITY:
RESEARCH AND FLIGHT EXPERIMENT OPPORTUNITIES

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NASA RESEARCH ANNOUNCEMENT

FUNDAMENTAL MICROGRAVITY PHYSICS: RESEARCH AND FLIGHT EXPERIMENT OPPORTUNITIES

This NASA Research Announcement (NRA) solicits fundamental physics proposals for flight definition experiments that can take advantage of the unique space environment aboard the International Space Station and for ground-based research with the potential for future flight. Ground based research can be experimental or theoretical in nature and can also cover development of innovative research enabling technologies. The fundamental physics discipline represents a broad range of research areas in the sub-disciplines of low temperature and condensed matter physics, laser cooling and atomic physics, gravitational and relativistic physics, and biological physics.

Investigations selected for flight experiment definition must successfully complete a number of subsequent development steps, including NASA and external peer reviews of the proposed flight experiment, in order to be considered for a flight assignment. NASA does not guarantee that any investigation selected for flight definition will advance to flight experiment status. Proposals are sought for a number of upcoming flight opportunities aboard the International Space Station. Ground based research investigators selected from this NRA must propose again to a future solicitation in order to be selected for a flight opportunity.

Participation is open to U.S. and non-U.S. investigators and to all categories of organizations: industry, educational institutions, other nonprofit organizations, NASA centers, and other U.S. Government agencies. **Though NASA welcomes proposals from non-U.S. investigators, NASA does not fund Principal Investigators at non-U.S. institutions.** Proposals may be submitted at any time during the period ending May 15, 2000. Proposals will be evaluated by science peer reviews and engineering feasibility reviews. Late proposals will be considered if it is in the best interest of the Government.

Appendices A and B provide technical and program information applicable only to this NRA. Appendix C contains general guidelines for the preparation of proposals solicited by a NRA.

This announcement will not comprise the only invitation to submit a proposal to NASA for access to the reduced-gravity environment and is part of a planned sequence of solicitations inviting proposals in the disciplines of the microgravity program.

NASA Research Announcement Identifier:	**NRA-00-HEDS-02**
NRA Release Date:	**February 15, 2000**
Letters of Intent Due:	**March 13, 2000**
Proposals Due:	**May 15, 2000**
Selection Announcement:	**September 2000**

This NRA is available electronically and Letters of Intent can be submitted electronically via the Microgravity Research Division Web Page at:

http://microgravity.hq.nasa.gov/

Alternatively, Letters of Intent may be submitted via e-mail to the following address: loi@hq.nasa.gov
If electronic means are not available, you may mail Letters of Intent to the address given below.

Submit Proposals to the following address

Dr. Mark C. Lee
NASA c/o InDyne, Inc.
Subject: NASA Research Proposal (NRA-00-HEDS-02)

300 D Street, S.W., Suite 801
Washington, D.C. 20024
Telephone number for delivery services: (202) 479-2609

NASA cannot receive deliveries on Saturdays, Sundays or Federal holidays.

Proposal Copies Required: **15**

Proposers will be notified by electronic mail confirming receipt of proposal approximately 10 working days after the proposal due date.

Obtain programmatic information about this NRA from:

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Your interest and cooperation in participating in this effort are appreciated.

Arnauld E. Nicogossian, M.D.
Associate Administrator,
Life and Microgravity Sciences and Applications

APPENDIX A
NRA-00-HEDS-02

TECHNICAL DESCRIPTION

FUNDAMENTAL PHYSICS IN MICROGRAVITY: RESEARCH AND FLIGHT EXPERIMENT OPPORTUNITIES

I. INTRODUCTION

A. BACKGROUND

The Human Exploration and Development of Space (HEDS) Enterprise, one of four National Aeronautics and Space Administration (NASA) strategic enterprises, conducts a program of basic and applied research using the unique attributes of the space environment to improve the understanding of fundamental physical, chemical, and biological processes. The Microgravity Research Division (MRD) program ranges from applied studies into the effects of conditions only available in space (such as low gravity) on the processing of various materials, to basic research that uses the space environment to create test conditions to probe fundamental laws of nature and the behavior of matter. This announcement is part of an ongoing effort to develop research in a specific scientific discipline, Fundamental Physics. The Division last released a NASA Research Announcement (NRA) for Microgravity Fundamental Physics in 1996 and expects to continue to release NRAs in microgravity Fundamental physics every two years.

NASA has supported research in Fundamental Physics for over two decades. Initially, the program focused on studies of critical phenomena in the Low Temperature and Condensed Matter Physics (LTCMP) area. Currently, the program also includes research in the fields of Laser Cooling and Atomic Physics (LCAP) and Gravitational and Relativistic Physics (GRP). With this solicitation, NASA is interested in further expanding this research discipline into the area of Biological Physics (BP), where a space environment may be advantageous. This growing research program also supports theoretical and experimental investigations in ground-based laboratories. These studies form the foundation for our research program, and serve as the intellectual underpinning of the investigations to be conducted in space.

In the MRD program, ground-based research has been used to gain a preliminary understanding of phenomena, and to define experiments to be conducted during extended exposure to the space environment using spacecraft in low-Earth orbit. MRD is developing several instruments to conduct fundamental physics research that offer improved research capabilities over early experiments. These instruments are configured to investigate critical phenomena, low temperature physics, and laser cooling and atomic physics. MRD also anticipates that flight opportunities for investigations requiring development of new instrument capabilities will be made available.

The primary focus for future MRD research will be on flight opportunities using International Space Station research instruments. MRD is currently studying the development of modular research instruments that can be configured (or reconfigured) to accommodate multiple experiments and multiple users. This is envisioned as an evolutionary program with the objectives of providing experimental data in response to increasingly sophisticated science requirements and of permitting the evolution of experimental approaches and technologies as needed for scientific investigations throughout the era of the International Space Station. This announcement is being released as part of a coordinated series of discipline-directed solicitations intended to span the range of the MRD program. Other MRD-supported solicitations are in the following areas:

Biotechnology
Combustion Science
Fluid Physics
Materials Science

B. RESEARCH ANNOUNCEMENT OBJECTIVES

This NRA has the objective of broadening and enhancing the MRD fundamental physics in the space program, the goals of which are described in Section II, through the solicitation of:

1. Flight definition experiment concept studies that will define and utilize new instruments for space-based experiments in fundamental physics. Research involving small, simple instruments are emphasized;
2. Ground-based experimental studies leading to the definition of future flight experiments or that will enhance the understanding of current or potential flight experiments in fundamental physics;
3. Ground-based theroretical studies that will support current or potential flight experiments in fundamental physics;
4. Ground-based technology development activities that will enable future experiments in fundamental physics.

Further programmatic objectives of this NRA include those broadly emphasized by the civil space program: the advancement of economically significant technologies; technology infusion into the private sector; enhancement of the diversity of participation in the space program, public education and outreach, and several objectives of specific importance to the microgravity research program. These latter objectives include: the support of investigators in early stages of their careers, with the purpose of developing a community of established researchers for the International Space Station and other missions in the next 10-20 years.

In support of the HEDS Enterprise goal to "Enrich life on Earth through people living and working in space," individuals participating in the microgravity research program are encouraged to help foster the development of a scientifically informed and aware public. The microgravity research program represents an opportunity for NASA to enhance and broaden the public's understanding and appreciation of the value of research in the space environment.. Therefore, all participants in this NRA should include in their proposal, a plan to promote general scientific literacy and public understanding of microgravity sciences, the space environment, the Fundamental Physics Program, and the investigators own work, through formal and informal education opportunities and through direct communication to the public. This plan may be judged as part of the Research Proposal Evaluation and Selection process (see Section XI of this NRA). Such education/public outreach might include:

- Education activities involving the training of undergraduate, graduate students and post-doctoral appointees;
- Development and utilization of outreach programs involving educational institutions, civic groups or industry; and
- Public information programs utilizing mass media, including webpages on the internet.

C. DESCRIPTION OF THE ANNOUNCEMENT

With this NRA, NASA is soliciting proposals to conduct research in fundamental physics with an emphasis on flight definition experiment efforts in new research areas for upcoming space flight opportunities. Funding will also be made available for ground-based experimental and theoretical studies, as well as technology development studies to enable future fundamental physics investigations. The goals of the discipline are described in Section II along with some research areas that have already been identified to be of interest. Proposals describing innovative fundamental physics research in space beyond that described herein are also sought.

NASA is currently developing several types of flight hardware for microgravity fundamental physics research using the International Space Station. A key element for the fundamental physics program is the

Low Temperature Microgravity Physics Facility (LTMPF). The LTMPF provides a 1.6 Kelvin instrument environment for up to 5 months. Another key element is Laser Cooling and Atomic Physics (LCAP) hardware under development to support planned clock experiments. A brief description of the LTMPF, of the LCAP hardware, and of other existing and planned capabilities is given in Appendix B, Section I. NASA expects to make funding available for several flight opportunities in the 2006 timeframe for investigations that can be met by either LTMPF instruments or by using planned LCAP hardware as building blocks.

NASA policy is to make maximum use of multiple year grants. A Multiple Year Grant is generally selected for a period of three years in keeping with NASA's policy calling for research to be peer reviewed at least every three years. Grants with periods of performance in excess of three years may be appropriate when NASA technical office determines at the inception of the grant that a period of performance in excess of three years is necessary to complete a discrete research effort.

Selected proposals will be funded for definition studies to determine the parameters and conditions for a flight experiment and the appropriate instrument flight hardware. The length of the definition phase will be based on the experiment requirements, but is typically completed within 36 months from the time funding is first made available. Key milestones during the definition phase are the Science Concept Review (SCR), which must be held within 24 months, and the Requirements Definition Review (RDR). Authorization to proceed into flight development is contingent upon successfully passing both reviews, where science, engineering and management panels review the Science Requirements Document (SRD) and the plans for implementing the proposed experiment.

NASA does not guarantee that any experiment selected for flight definition will advance to flight experiment status. In fact, to ensure that the highest quality experiments are flown in space, MRD will strive toward selecting, on average, up to two experiments for flight definition for each experiment that will actually fly. Flight investigations that do not proceed into flight development will be asked to submit a proposal for continuation of flight definition support at the conclusion of a typical four-year period of funding. Promising flight definition proposals that are viewed by NASA as not mature enough to allow development of a flight concept within two years of definition may be selected for support as ground-based research tasks instead. Investigators selected into the ground-based research program must propose again to a future announcement in order to be selected for a flight opportunity.

II. FUNDAMENTAL PHYSICS RESEARCH IN SPACE

Not all problems in physics can benefit from the environment of space. Excluded are, for example, many experimental studies where inter-particle or inter-atomic interactions are so strong as to totally mask gravitational forces. Problems in physics where the space environment can be beneficial include :

- those subfields where interactions are weak;
- where extremely uniform samples free from hydrostatic compression are required;
- where objects must be freely suspended and their acceleration must be minimized;
- where space offers a unique environment not available on the Earth;
- where the mechanical disturbances, unavoidably present in an Earth-bound laboratory, must be eliminated.

A first category of experiments can benefit either from the dramatically reduced gravity available in space, or from the use of variable gravity as a parameter whose change may lead to the elucidation of otherwise hidden properties and phenomena. The physics of critical points in fluids is prominent among the issues in condensed matter physics that have been investigated so far under microgravity conditions. Microgravity plays an important role in these investigations because the closeness of approach to a critical point in the Earth-bound laboratory is limited not by the skills of the experimentalist, but rather by the uniformity of the sample which is spoiled by hydrostatic pressure variations. A second category of phenomena currently under investigation comes from the field of atomic physics. The aim here is to retain atoms virtually without motion in a cavity for extended time intervals. However, the length of time that the atoms can be held in the cavity is limited by the gravitational acceleration experienced on Earth. This second category also includes the study of freely suspended rotating superfluid-helium drops. A third category of investigations will benefit from the opportunity to virtually eliminate all mechanical disturbances in space. For example, such disturbances limit proof-mass technique experiments probing fundamental questions in gravitational and relativistic physics, where the positions of objects relative to each other must be maintained and measured with a resolution unobtainable in the gravitationally noisy environment on Earth. A fourth category of investigations benefit not from the microgravity of orbital flight, but rather from other aspects of the space environment, such as the availability of new Space-Time coordinates for tests of relativity theories.

One of the unifying characteristics of physics as a whole is that the field addresses fundamental issues that transcend the boundaries of a particular field of science. It is typical that, at one extreme, the fundamental laws of our universe, such as the law of gravitation or the laws that rule the quantum world, should be a central issue. Clearly these laws are relevant to various extents in many branches of science. At another extreme, in condensed matter physics, those unifying principles are studied which arise from the interaction of many degrees of freedom on vastly different length scales. Examples of this type of study can be found in the research on critical phenomena mentioned above, which addresses fundamental problems of nonlinear physics that pertain equally to fluid, solid-state, chemical, or biological systems.

The space experiment represents an opportunity to extend a set of measurements beyond what can be done on Earth, often by several orders of magnitude. This extension can lead either to a more precise confirmation of our previous understanding of a problem, or it can yield fundamentally new insight or discovery. NASA maintains a vigorous program of Earth-bound projects, together with an appropriate number of space-based investigations. The motivation for this dual approach to maximizing scientific output is two-fold. Firstly, in most cases, only a vigorous ground-based program will identify the experiments that are most worthy of consideration for space. Thus, it is expected that the space experiments are a natural outgrowth of the ground-based program. Secondly, a space experiment should have been performed on Earth to its maximum potential. This should determine whether a highly complex experiment will be successful when conducted in space. It also ensures that the value of the science knowledge to be gained by a space experiment cannot be greatly diminished by Earth-bound experiments.

The following sections describe the research areas covered by this announcement. They have been organized into sections on Laser Cooling and Atomic Physics (LCAP), Low Temperature Physics and Condensed-Matter Physics (LTCMP), Gravitational and Relativistic Physics (GRP), and Biological Physics (BP). However, proposals of innovative microgravity fundamental physics research beyond that described below are also sought.

With this solicitation, NASA intends to select both flight-definition and ground based research proposals. Approximately, a maximum of 6 to 7 innovative flight-definition investigations for the ISS in the 2006 timeframe are targeted for support. Approximately 30 to 40 ground-based investigations covering experimental studies with the potential for future flight, theoretical studies to support current or planned flight experiments, and investigations aimed at developing research-enabling technology will be supported. Section III in this Appendix describes the technology development solicitation in more detail. Actual numbers of selections will be influenced by response from the scientific community. A description of research hardware under development can be found in Appendix B, Section I.

A. LASER COOLING AND ATOMIC PHYSICS (LCAP)

One of the most dramatic advances in atomic physics over the last decade has been the demonstration that laser light can be used to cool a dilute atomic sample to within nano-degrees of absolute zero. At these low temperatures, the mean velocity of the atoms drops from several hundred meters per second to centimeters per second or even smaller, a reduction by four to five orders of magnitude. In this quantum regime, the gravitational energy far exceeds the mean atomic kinetic energy and the effects of gravity dominate atomic motion. For example, the energy gain of a cesium atom as it falls a centimeter in Earth's gravity corresponds to an increase in its temperature of 1500 microkelvin, while a lighter atom such as lithium gains 80 microkelvin per centimeter.

1. <u>Fundamental Forces and Symmetries</u>. Almost every precise measurement made in science ultimately traces back to a time or frequency measurement (thermometry, distance, pulsar period, etc.).. However, the potential use of ultra-high precision cold-atom clocks in space has deeper significance. At the heart of the atomic clock is a measurement of a carefully chosen energy level splitting within the atom. These splittings are not only nature's own reference "standards" but, at the resolution which can be expected using space clocks, the splittings become measurably sensitive to subtle aspects of fundamental forces and to basic symmetries of nature. Usually, these last classes of questions are the realm of high-energy or "particle" physics. Ultra-high precision atomic measurements, however, can now make important contributions to answering these questions, and the use of space can play a vital role in enhancing this contribution. For example, parity non-conservation experiments in atomic cesium already compete with accelerator based measurements for the determination of the Weinberg angle, a direct measure of the electroweak mixing angle in the Weinberg-Salam model (and a number which determines the ratio of the W to Z boson masses). As with any clock type measurement, one important limitation of these experiments is the observation time. This limitation can be overcome in space experiments.

A related issue is the search for the permanent Electric-Dipole Moment (EDM) of the electron. The existence of an EDM can be traced directly to time reversal (T) and/or charge-conjugation parity (CP) violating interactions, or in other words, to the most basic symmetry properties of nature and of the physical laws describing nature. The EDM measurement consists of a ***very precise*** determination of the response of the atomic level splitting to an applied electric field. Essentially, this is a clock-type measurement. Using the space environment, a cold-atom clock can provide at least ***two orders of magnitude of improvement*** in accuracy over current EDM measurements. Regardless of the exact outcome of the EDM experiments, the results are essentially ***guaranteed*** to be significant: If this experiment detects no moment, several theories of CP violation competing with CP-violating interactions present in the standard model can be eliminated, such as CP violating interactions in super-symmetry, flavor changing, etc. On the other hand, detection of a moment will demand far-reaching revisions in the foundations of physics..

2. <u>Bose-Einstein Condensation and Quantum Gasses</u>.. The physics of laser cooled vapors is closely tied to the physics of quantum fluids and statistical mechanics. Dramatic phase changes such as the condensation of large numbers of atoms into the lowest state of the system, called Bose-Einstein condensation, are being investigated by the laser-cooling community and new insight into quantum transport phenomena is steadily being gained. As lower and lower temperatures are achieved using evaporative cooling, gravitational limitations have already emerged. For example, the energy bias introduced by the gravitational field may vastly reduce the efficiency of evaporative cooling, the final cooling step used to pass into the Bose condensed phase. Furthermore, the investigation of freely expanding sub-nanokelvin condensates, as well as very dilute condensates, will become increasingly difficult and, eventually, impossible on Earth's surface due to gravitational effects. Within this component of LCAP, a strong synergy with related work in Low Temperature and Condensed Matter Physics is expected.

Since the first observations of BEC in a dilute atomic vapor, several important areas of research have emerged which may benefit from access to space.. These include BECs with internal structure such as spinor BECs and multi-component BECs. These complex condensate systems have already been shown to exhibit rich behavior including phase segregation, pattern formation and some indications of superfluidity. The study of complex BECs is expected to provide new exciting insight into the bridge between degenerate atomic vapors and the fundamental notions of condensed matter physics. However, many aspects of the underlying physics compete with gravity in the system energetics. Another exciting development has been the generation of dense ultracold vapors of atoms which obey Fermi statistics. Theoretical predictions indicate that Bardeen-Cooper-Schrieffer-(BCS)-like pairing should be observable, but that it will occur at exceptionally low energy scales where even small variations in gravitational potential energy may disrupt the state formation. Lastly, the atomic vapor BEC is also recognized as the premier source of atoms in terms of source brightness with important application to many problems in atomic physics and atom optics.

3. Atomic Interferometers

Reaching far beyond the initial goal of demonstrating the interference of matter waves of massive, complex particles, the atom interferometer is now used to realize high performance rotation sensors (gyroscopes) and gravitometers that provide unprecedented sensitivity. As in other LCAP experiments, the elimination of gravity can allow significant improvements in many interferometry experiments. Of additional importance is the application of space based atom optics and interferometry experiments to fundamental problems such as improving our knowledge of the gravitational constant G (the least well known of all fundamental constants of nature) as well as to terrestrial applications such as ultra-high performance geodesy. Furthermore, there are significant opportunities for space atom interferometry experiments to complement other fundamental physics experiments in general relativity and gravitation. For example the comparative testing of the Equivalence Principle for macroscopic (classical) bodies, as investigated by the Satellite Test of the Equivalence Principle (STEP) (see below), and for microscopic (quantum) particles, as investigated using atom interferometer based gravitometers.

4. Atom Optics

The atom interferometer is but one example of the remarkable devices being developed in the field of atom optics, which explores the analogy between de Broglie matter waves and ordinary electromagnetic light waves. Atomic lasers in which matter waves are coherently coupled out of Bose-Einstein condensates have been demonstrated, along with atomic mirrors, beamsplitters and nonlinear 4-wave mixing devices. In many of these experiments gravity plays a dramatic role, and we thus expect that new and novel devices will be proposed that require a space environment.

5. Atomic Clocks.. An important technological contribution of modern atomic physics is the development of ultra-high precision clocks. These clocks not only provide the standard by which we tell time, but they are crucial to the way we communicate and navigate on Earth, in the air, and in space. Two vital concerns in the conception of such ultra-high precision devices are : (1) that the precision is inversely proportional to the observation time [this stems from the uncertainty relation ($\Delta E \Delta t \geq h/2\pi$)] and (2) that the first- and second-order Doppler shifts associated with motion of the atoms can cause broadening of the atomic transition, thereby compromising the measurement accuracy and precision. Laser-cooled atoms have significantly pushed back both of these limitations. Very cold atoms move ***very*** slowly, reducing Doppler shifts, and they remain in a given observation volume for ***very*** long times, thereby reducing line broadening caused by the uncertainty relation. Indeed, compact cold atom clocks have already been built and have provided a short-term stability that is significantly better than the existing standards. Nevertheless, limits on observation times in these clocks are still set by gravity. Ultimately, the atoms fall out of the experiment under their own weight. Increased observation times are thus possible in a freely falling spacecraft and can result in further improvements in clock stability by at least one or two orders of magnitude. A long-term accuracy, near one part in 10^{17} is expected, making these clocks three orders of magnitude better than currently accepted standards, and additional orders of magnitude better than most space ready clocks.

High performance space clocks can have a deep impact on our understanding of nature. For example, the development of an ensemble of high performance space clocks that operate on different physical processes will allow unique tests of fundamental physics. Relative drifts between the clocks can be used to detect the drift between the coupling constants of different fundamental forces, coupling constants that lie at the very heart of the accepted description of nature. See the Gravitational Physics section below for further details.

B. LOW TEMPERATURE AND CONDENSED MATTER PHYSICS (LTCMP)

In this research area, NASA is interested in selecting: innovative flight-definition investigations that can take advantage of future opportunities aboard the LTMPF; ground-based experimental investigations with a potential for future flight; theoretical investigations supporting current or future flight experiments; investigations aimed at developing research enabling technology. The description for research enabling technology can be found in Section III of this Appendix. The description of the LTMPF and other research hardware under development can be found in Appendix B, Section I.

1. Critical Phenomena. The theoretical foundation of understanding critical phenomena is provided by the Renormalization Group (RG) theory. The physics of critical-point systems is extremely diverse, but at the same time, it is unified through the framework of the RG theory. Different phase transitions can be categorized as belonging to different universality classes according to general symmetry properties of the order parameter and the conservation laws of the system. Two important critical points, belonging to different universality classes, are the superfluid transition in liquid helium and the liquid-gas critical point. Within a given universality class, the critical behavior of various properties is predicted to be the same except for a small number of constant multiplying factors that are system specific. A third important system is the tricritical point in ^3He-^4He mixtures. Tricritical points are very special because, for them, the leading critical behavior is given exactly by mean-field theory. In this case, the RG theory makes exact predictions about corrections to this mean-field behavior. These corrections take the form of fractional powers of logarithms.

Room temperature critical point experiments concerning the turbidity of fluids near gas-liquid critical points can provide new information about the interactions of the density fluctuations. Microgravity experiments can measure the turbidity of large regions that are very near the critical point, thus enabling larger fluctuations to be explored so new regions of the parameter space can be investigated.

2. Solid-Fluid Interfaces. One important issue in condensed matter physics concerns the nature of the interface between solids and fluids. The boundary conditions that prevail at this interface have an influence on macroscopic phenomena, including wetting, surface phase transitions, and film formation. The microscopic aspects of the system near the boundary are difficult to study. However, when the fluid is near a critical point, the boundary layer adjacent to the solid surface acquires a macroscopic thickness. If the fluid phase is of limited spatial extent, the boundary will then significantly influence the average macroscopic properties of the system. Thus, a critical fluid system that is confined can be used to study boundary effects.

These finite-size effects can take several forms, depending on the nature of the confinement. For instance, the sample might be contained between parallel plates, as is the case for the Confined Helium Experiment (CHeX). On the other hand, quantitatively different results are expected when the fluid is contained in long, narrow cylinders. Again the RG theory is expected to provide a unifying framework for understanding these phenomena. Large-scale computations using Monte Carlo methods with suitable models can also be used to study these effects. In these theoretical studies the boundary conditions and the confining geometry can be varied in a controlled fashion. Interesting issues include not only the influence of the boundaries on thermodynamic properties; but also of interest are transport properties such as heat or mass transport.

3. The Physics of Thick Fluid Films. The study of fluid films under typical terrestrial conditions is limited to films with a thickness no more than tens of nanometers because thicker films will “drain." Interesting new physics could be learned from the study of thicker films that would be available in a free-fall environment. Some of the interesting issues to be addressed include the problem of the superfluid transition in liquid helium: although helium can be studied when confined between two rigid plates of separation d, the film of equal thickness d has the potential to yield information about the difference in boundary conditions at the liquid-vapor and liquid-solid surfaces. This issue of boundary conditions is of fundamental importance in condensed matter physics. Another issue of interest in thick superfluid helium films is the nature of sound propagation within them. One expects interesting behavior when, as the thickness of a superfluid film increases, one encounters the crossover from "third sound" (a tidal wave) on the film to "second sound" (a temperature wave that propagate in bulk superfluid helium). Almost certainly a number of other fundamental issues will arise, as the study of thick films becomes available in the space environment. For example, third sound is dominated by van der Waals forces in thin films but, as the thickness increases, surface tension becomes a more important force, and the crossover in behavior has not been well studied.

4. Non-equilibrium Systems. Nature displays many non-equilibrium systems that are constantly evolving. Yet most studies of physics consider the idealized case of equilibrium. The statistical dynamics of many-particle systems in metastable equilibrium or in non-equilibrium is an important field of physics that is far from being well developed and well understood. When non-equilibrium phenomena have been considered, this usually has been done within the framework of linear response theory that applies when departures from equilibrium are small. Indeed, in laboratory systems it is often difficult to achieve sufficiently extreme conditions for linear response theory to break down under well-controlled circumstances that permit quantitative study. However, such conditions can be achieved more readily in the vicinity of critical points where typical relaxation times become large. Thus, we can exploit the criticality of a system to explore extreme non-equilibrium conditions where transport becomes a nonlinear phenomenon. The superfluid transition of ^{4}He is a system that is particularly suitable for the study of these phenomena. Aspects such as the effect of non-equilibrium conditions on thermodynamic properties and on the behavior of confined systems can be studied. One possible method to generate non-equilibrium conditions is to inject large-amplitude sound waves into a fluid; studies of the phenomenon of sonoluminescence that can result may benefit from experiments in space. Studies of non-equilibrium conditions in ^{3}He-^{4}He mixtures and measurements of viscosity near a critical point may also benefit from the space environment. Many other subjects are available for study in this largely unexplored fundamental subject area of dynamics near critical points.

5. Superfluid Hydrodynamics. A number of highly interesting experiments in superfluid hydrodynamics exists which can be carried out under free-fall conditions. One class addresses the intrinsic nucleation problem for quantized vortices in helium II. Almost all nucleation experiments suffer from extrinsic nucleation effects. For example, rotation of a bucket of superfluid always produces an array of quantized vortices that appear at velocities much lower than would be expected for intrinsic nucleation. Very likely, residual vortices pinned to the boundaries are responsible. If we study the dynamics of a liquid drop suspended away from any boundaries, and if the temperature is low enough that vapor around the drop is for all practical purposes gone, then there cannot be any way to have pinned vortices and presumably vortex nucleation must be truly intrinsic.

In yet another experiment, a helium drop could be rotated rapidly to observe the deformation from the spherical shape against the force of surface tension. Much theoretical work exists on the shapes of rotating fluids, and one space experiment has been performed already on the space shuttle using water as the working fluid. Using superfluid helium or other quantum fluids as working fluid can further enhance this research field.

Creation and suspension of drops offers other classes of experiments studying collisions of drops and coalescence. One could even imagine studying the collisions of ^{3}He and ^{4}He drops, or a suspension of one or more ^{4}He drops in liquid ^{3}He. Experiments with drops of liquid or solid hydrogen could also be done. At low enough temperatures, hydrogen also behaves as a quantum fluid (or solid), and even as a superfluid, providing new scientific insight.

6. Melting-Freezing and the Growth of Crystals. First-order phase transitions, involving the processes of melting and freezing and of crystal growth, have long been of fundamental interest to physicists and of practical importance to material scientists. Extensive and detailed studies of a wide range of physical processes associated with first-order transitions have been carried out. Prominent among the issues of interest are the mechanisms involved in the transfer of atoms from liquid to solid and vice-versa, nucleation (initiation) of a new phase within an existing one, and diffusive and ballistic mass transport. In addition, an important aspect of crystal formation involves the phenomena that govern the evolution of crystal shapes, that is, the so-called roughening transition and associated phenomena. In the presence of gravity, various forms of convective flow have inhibited detailed studies of many of these processes.

Helium offers unique opportunities for these studies for several reasons. The first of these is its quantum nature that offers the opportunity to study properties not accessible in ordinary (classical) solids. The second includes several characteristics that make such studies possible under free-fall conditions. As an example of these characteristics, we note the relatively fast diffusion, and resulting short relaxation times for shape changes, of helium crystals on their approach to equilibrium. This rapid approach to equilibrium is in contrast to classical solids for which these times are often prohibitively long, especially in comparison to time scales accessible to space experiments.

Studies of the quantum nature of the solidification process of hydrogen may also benefit from a reduced gravity environment.

C. GRAVITATIONAL AND RELATIVISTIC PHYSICS

In this research area, NASA is interested in selecting: innovative flight-definition investigations that can take advantage of future opportunities aboard the LTMPF; ground-based experimental investigations with a potential for future flight; theoretical investigations supporting current or future flight experiments; investigations aimed at developing research enabling technology. In particular, with this NRA NASA would like to challenge the scientific community to find cost effective means to answer the important research questions raised below, ideally by making use of the LTMPF and innovative instruments. The description for research enabling technology can be found in Section III of this Appendix. The description of the LTMPF and other research hardware under development can be found in Appendix B, Section I.

Tests of Einstein's theories of relativity and of other metric and non-metric theories of gravitation serve as a foundation for understanding how matter and space-time itself behave at large length scales and under extreme conditions. The free fall environment of space, the use of low temperature techniques, and the use of high precision frequency standards, offer opportunities to perform improved tests of these theories significantly beyond what is possible on the ground.

Einstein's Equivalence Principle (EEP) provides a foundation for all metric theories of gravity. To verify the range of validity of different EEP aspects is crucial to the quest for unifying all fundamental forces of nature. Gravitation, electromagnetism, and the weak and strong interactions in nuclei, are the four known fundamental forces of Nature. The present theory of gravity is intimately connected to the theory of General Relativity. General Relativity is a “classical”, non-quantum theory of curved spacetime and it constitutes an as yet unchallenged description of gravity interactions at macroscopic scales. The other three forces are described by a quantum field theory called the “Standard Model” of particle physics, which accurately describes physics at short distances where quantum effects play a crucial role.

Despite the beauty and profundity of Einstein's theory and the success of the “Standard Model,” our present understanding of the fundamental laws of physics has serious shortcomings. At present no realistic theory of quantum gravity exists. The “Standard Model” successfully accounts for all existing non-gravitational particle data. However, just as in the case of General Relativity, it is not a fully satisfactory theory. It suffers from unresolved problems concerning the violation of the CP symmetry between matter and antimatter and the various unexplained mass scales. Purported solutions to these shortcomings typically involve new interactions that could manifest themselves as apparent violations of the EEP. One should note the relevance of the precision measurements of the laser-cooling experiments to Gravitational and Relativistic Physics in mounting challenges to the Standard Model with tests like the search for a finite electric dipole moment in the electron, a test of time reversal symmetry.

It has been experimentally verified that gravity couples to light, or photons, the massless particles that “mediate” the electromagnetic force. In the same manner, gravity should also couple to the other massless particles that mediate the interactions between the many sub-atomic particles. The way in which gravity couples to the total mass-energy of matter is key to understanding the EEP.

The construction of a “Grand Unified Theory” of weak, electromagnetic and strong interactions seems to require, for theoretical as well as experimental reasons, the existence of a supersymmetry between particles of different spins. This framework suggests the existence of new interactions beyond those of the “Standard Model”. In particular, the exchange of new spin-one particles could lead to a new repulsive force between macroscopic bodies, which might be detected through small deviations from the EEP.

The truly outstanding problem remains the construction of a consistent quantum theory of gravity, a necessary ingredient for a complete and unified description of all particle interactions. Superstring theories, in which elementary particles would no longer appear as pointlike, are the spinless partners of the graviton: “dilatons” and axion-like particles. The dilaton, in particular, could remain nearly massless and induce violations of the EEP at a level that may be detectable.

In a space environment, the weak equivalence, local Lorentz invariance, and local position invariance aspects of EEP can be tested independently at high precision. High-resolution experiments can use ultra-sensitive superconducting test mass techniques to test the weak equivalence principle with many orders of magnitude better precision than previously accomplished. Using high stability frequency standards in various arrangements can test other aspects of EEP. The clock itself reaches deeply into the foundations of physics. As is apparent in any discussion of relativistic effects, clocks are central in the realm of general relativity and in questions concerning the very nature of gravity itself. Here the motivation for space-based clocks is tied not only to the improved performance expected in a space environment, but is also tied to the fact that these clocks will have access to ***fundamentally different positions in space-time than are available on Earth***.. An important example of this latter physics is that revealed in the comparison of an Earth-based clock with a space-based clock. This comparison provides a direct measurement of the gravitational red shift, the reduction of frequency caused by a change in the clock’s gravitational potential. Indeed, improvements of one to two orders of magnitude of the current accuracy of 70 parts per million can be expected using space-based ultra-high precision clocks to measure these shifts. Measurements of the gravitational red shift also test important aspects of the local position invariance part of Einstein's Equivalence principle and are tied to the possible spatial variation of the fine-structure constant α, a parameter central to quantum electrodynamics.

Direct tests of gravitation theories and of other fundamental theories can also be performed advantageously in a space environment. Superconducting accelerometer test mass techniques and frequency standards techniques can be used to study the Lense-Thirring effect, test the inverse square law of gravitation, and to search for weak coupling forces through axions and through other potential near-massless bosons.

Applications of gravitational physics to Astronomy, such as the search for (and use of) gravitational waves, is considered to be under the program responsibility of the Office of Space Science and is not covered by this solicitation.

D. BIOLOGICAL PHYSICS

This is the first time the Microgravity Research Division is soliciting research in this area. To this end, NASA is interested in hearing from this research community about potential research areas at the intersection between physics and biology where experimentation in a space environment could provide a benefit. To learn more about this prospect, NASA is interested in selecting : ground-based experimental investigations with a potential for future flight aboard the ISS ; theoretical investigations in support of future flight experiments ; investigations aimed at developing research-enabling technology. The description for research enabling technology can be found in Section III of this Appendix. The description of the LTMPF and other research hardware under development can be found in Appendix B, Section I.

The physical sciences form the underpinning for the life sciences, the study of the physical principles that govern biological systems will have a profound fundamental impact on our understanding of biology. Many physicists have been drawn to the study of biology by the desire to understand the mechanisms of living organisms. They have found a niche in applying their scientific methods to problems that lies at the boundaries of physics, chemistry, and biology. Some (like Francis Crick) have profoundly contributed to our understanding of life. Others have found that their skill as instrumentalists can change medicine, as evidenced by such advances as tomography and magnetic resonance imaging. While still others have used their skills in mathematics to propose theories for neural networks, electron transfer and non-linear phenomena such as heart rhythms. Working in concert with life scientists and thereby forming interdisciplinary teams, physicists can not only probe complex biological problems but also help to guide and develop new devices based upon observing biological systems. Nature abounds with examples where one or more of the underlying mechanisms governing the function of a biological process may reveal new insights into physical processes. In a variety of biological systems, the transfer of energy from one form (i.e., mechanical) into another (chemical) takes place. The interface between biology and physics will be a rich instructional base for the development of novel approaches for sensors and other devices.

With this solicitation, NASA is welcoming research in biology that is profoundly connected to the principles of physics. In such research, the understanding of the underlying physics, which may be closely tied to the effects of earth's gravity, should be moved forward.

We seek innovative physics research that:

a) Advances our understanding of processes or materials involved in biological systems.

b) Provides an enhancement in the analysis of experimental data or theory.

c) Applies advances in physics instrumentation to biological systems.

d) Addresses new phenomena of a primarily physical nature in a biological system.

Examples of these areas of research include:

Fabrication. Nature has many examples of structures whose design is patterned in the genetics of the organism. Understanding the physical forces underlying the formation of these three-dimensional structures will permit the formulation of synthetic monomers that can be used to fabricate similarly complex structures. These three dimensional structures would find value in data storage and integrated circuits.

Receptors. The diversity of molecules to which biological systems must respond is matched by an equally diverse set of receptors. These receptors function largely by a network of hydrophobic, ionic and other noncovalent interactions. Elucidating the physical forces that govern individual interactions between a receptor and its ligand combined with influence of architecture on the overall binding affinity is essential. It will provide insight into the design of molecules to serve as novel receptors in sensors.

Signal transducers. Receptors bind to their targets employing a network of noncovalent interactions that are then translated into subtle structural changes. These conformational changes occur on a picosecond timescale making them potentially very rapid switches for other nonbiological applications. One of the critical features in adopting these structures is the relative frailty of proteins. Clearly an advance in biological physics will be in fabrication of these structures

Locomotion. Locomotion is a key element of many biological systems and it distinguishes them from inorganic, non-living systems. Elegant experiments where filaments are used as tethers to demonstrate their ability to translocate small spheres have been conducted. Conformational changes in the protein have been examined and used as the basis to elucidate the physical processes involved in filament contraction.

Nonlinear dynamics of biological systems. Advanced mathematical physics techniques have been used to study nonlinear effects, such as heart rhythms, in biological systems. Such research can be used to support experimental imaging studies and to develop improved models of predictive systems. These techniques can also be used in studies aimed at elucidating the origin of life.

Manipulation of biological specimens. Laser manipulation techniques, such as optical tweezers, have been used to advantage in many studies of widely diverse biological systems. Examples include the preparation and study of motor processes in muscle cells and the manipulating and study of DNA. It is anticipated that future innovation based in physics can be applied fruitfully to studies of this kind.

From these investigations fundamental insights into biological process will perhaps leading to the availability of the following products :

Biomaterials. Evolution has resulted in the fabrication of biomaterials that promote high performance in animals and plants. Biomaterials will be essential to solve problems in medicine and other areas that require unique materials designed to be for example compatible and not lead to an adverse immunological response. Natural selection has resulted in producing just the right material to perform the necessary job. In doing so, attention has been paid to minimizing the energy required, whether for biosynthesis or in achieving morphological stability or liability. This optimization tends to maximize performance. Novel materials inspired by nature but fabricated through human manufacturing processes will be possible in the future.

Sensors. There is a need for sensors to monitor the environment and to serve as warning systems for potential danger. Nature abounds with sensors that for example warn insects of predators or allow them to seek prey. Various animals and plants have sensors that are uniquely suited for their purpose and can sense stimuli well outside of the normal human scope of hearing, seeing, smelling and tactile senses. Biologically inspired sensors coupled to electronic signal transduction and readouts can extend the human capabilities. Understanding the physical basis for these sensors and then utilizing that knowledge to build sensors will be a benefit of this research.

All studies are required to have a significant physics investigation in a biological system as part of the proposal in order to be considered for funding.

III. DEVELOPMENT OF RESEARCH ENABLING TECHNOLOGY

This NRA also solicits speculative high-pay-off technology development activities that could enable new microgravity fundamental physics investigations to be performed in the future. MRD is planning to select two to four projects in this category. Funding will be at the same level as ground based scientific investigations (About $ 100,000 per year for up to 4 years.) Successful proposals are expected to be highly innovative and will aim to bring technology from the conceptual stage (readiness level 0 to 1) through to feasibility verification at the prototype laboratory stage (readiness level 3 to 4). An important selection criteria will the extent to which the proposed technology development supports the broader goals of allowing humans to enter, live, and work effectively in space, and the potential of the technology to enhance the quality of life for all Americans. With this solicitation, NASA is particularly interested in technology developments that in one way or another are targeting the use of quantum principles for their operation. Examples of technology developments that fall into this category are techniques based on quantum fluid behavior, such as superfluid helium gyroscopes; techniques based on atom interferometry, and techniques based on superconductivity.

IV. EXPERIMENTAL APPARATUS AND FLIGHT OPPORTUNITIES

A. EXPERIMENTAL APPARATUS

In order to accommodate aspects of the research described in Section II, a number of pieces of flight hardware are being developed by NASA and its international partners. These are described in Appendix B, Section I. Experimental apparatus for the Space Station will primarily be in facilities such as the Low Temperature Microgravity Physics Facility (LTMPF), the EXPRESS rack, and the Fluids Integrated Rack (FIR) which is part of the Fluids and Combustion Facility. Opportunities for small experiments to fly in the Glovebox also exist. A high-capacity communications network supports ISS payload operations. Downlink channels enable users to monitor their instrument status and science data streams in real time. An uplink channel enables them to act on that information.

Ground based apparatus is also available to support definition studies. These are listed in Appendix B Section II.

B. DIAGNOSTIC MEASUREMENTS

The capability to perform highly precise measurements on samples in a space environment is essential to scientific progress in this program. NASA is developing techniques for improving measurements of temperature and pressure, enhanced capabilities in the measurement of frequency, and enhanced imaging and visualization techniques. As these techniques mature, those most required by investigators will be qualified for space flight and made part of the future flight equipment capability.

C. FLIGHT OPPORTUNITIES

Missions targeted with this solicitation are primarily for extended duration (up to about six months) studies on board the International Space Station. Residual acceleration levels on the order of 10^{-4} g rms are available on the ISS for limited periods of time. The Space Acceleration Measurement System (SAMS) is expected to be available to measure and record actual accelerations at or near the apparatus for ISS experiments. Information about other environmental effects, such as the cosmic ray environment and the magnetic field environment, will also be made available to researchers. Considerable additional information on the ISS accommodations and capabilities can be found in the ISS Investigators' Guide (see Bibliography).

Shorter duration missions of 7 to 10 days' length could be made available on Shuttle flights also.

D. EXPERIMENT DEFINITION AND FLIGHT ASSIGNMENT PROCESS

Laboratory studies are usually necessary before clearly defined flight experiment objectives can be established. These studies are usually performed in ground-based facilities at the investigator's institution. NASA facilities can also be made available for this purpose should the need arise. These facilities are described in Appendix B, Section II. Successful flight definition proposals will be supported for a ground-based definition phase before review for flight assignment. The amount of support (technical, scientific, and budgetary) and the length of the definition period (up to approximately three years) will depend on the specific investigator needs and the availability of resources from NASA. However, in preparing their budget plan for this research announcement, all flight definition proposal respondents should estimate their annual costs through project completion. Budget information must be grouped into the areas of investigator science support and instrument development. NASA is only committed to provide investigator science support for 4 years. Funds in the instrument development category are released as needed pending successful review of the maturing experiment concept at review gates described below. Investigators that are proposing for flight are strongly urged to team up with flight hardware experienced contractors in preparing the instrument development sections and implementation plans for their proposals. It is also advisable for investigators proposing for flight definition to contact staff members at JPL early on in the proposal preparation process to begin understanding the details of the flight hardware development and qualification process.

A flight experiment represents a considerable investment of resources, both human and financial. The Principal Investigator for a flight definition investigation has the responsibility to continue the pursuit of basic knowledge which will make a flight experiment fully meaningful, and, in addition, will be responsible for major contributions to the effort needed to define and build the flight experiment. In the first six months following selection, the Principal Investigator will meet with NASA or JPL representatives to discuss any technical feasibility issues related to the proposed flight experiment. These discussions will also include development of a detailed plan, based on the proposed budget, for establishing feasibility, producing a draft Science Requirements Document (SRD), conducting the Science Concept Review (SCR) and conducting the Requirements Definition Review (RDR).

Within two years, the flight definition investigator will generate a preliminary Science Requirement Document (SRD). The preliminary SRD is reviewed along with the experiment concept at the SCR. Following a successful SCR peer review by science and engineering panels, the experiment will proceed to the RDR. Experiments that do not pass the SCR are placed in the ground-based program where NASA fulfills its 4-year commitment to the investigator. The RDR is usually held one year after the SCR and marks the conclusion of the definition phase. At the RDR, science and engineering panel members review the final SRD, the experiment concept, the experiment requirements, and the preliminary implementation plan. If the experiment has a successful RDR it transitions to the flight development phase and is considered for flight. NASA does not guarantee that any experiment selected for definition will advance to flight development status, and the possibility exists that investigations may be placed in ground-based status, with continuing support from NASA to fulfill on the initial 4-year commitment. In fact, to ensure that the highest quality experiments are flown in space, MRD will strive toward selecting, on average, two experiments for flight definition for each experiment that will actually fly. Investigations with unresolved science or engineering issues at the RDR may be placed in ground-based status for the remainder of NASA's 4-year commitment. The investigators must submit a new proposal to a subsequent solicitation to be considered for future flight opportunities.

V. GROUND RESEARCH PROPOSAL SUBMISSION INFORMATION

This section gives the requirements for submission of ground research proposals (including technology proposals) in response to this announcement. A Principal Investigator who is responsible for all research activities must direct ground research proposals submitted under this announcement. Proposal may include one or more Co-Investigators. Proposals must address all the relevant selection criteria as described in Section XI and must format their proposal as described in this section. Additional general information for submission of proposals in response to NASA Research Announcements may be found in Appendix C.

A. GROUND RESEARCH LETTER OF INTENT [also referred to as Notice of Intent (NOI)]

Organizations planning to submit a ground research proposal in response to this NRA should notify NASA of their intent to propose by electronically sending a Letter of Intent (LOI) via the MRD Web Page:

http://microgravity.hq.nasa.gov/

Alternatively, Letters of Intent may be submitted via e-mail to the following address: loi@hq.nasa.gov

If electronic means are not available, you may mail Letters of Intent to the address given for proposal submission in the following section. Facsimile transmission of the Letter of Intent is also acceptable. The MRD fax number is (202) 358-3091.

The Letter of Intent, which should not exceed two pages in length, must be typewritten in English and must include the following information:

- Principal investigator name, position, organization, address, telephone, fax, and e-mail address.
- A list of potential Co-Investigators (Co-Is), positions, and organizations.
- General scientific/technical objectives of the research.
- A statement identifying the proposal as being for ground-based study.
- A statement describing the proposal as scientific research or as a technology development.
- The equipment of interest listed in this NRA, if appropriate.

The Letter of Intent should be received at NASA Headquarters no later than March 13, 2000. The Letter of Intent is being requested for informational and planning purposes only, and is not binding on the signatories. Institutional authorizations are not required. The Letter of Intent allows NASA to better match expertise in the composition of peer review panels with the response from this solicitation. In the Letter of Intent, investigators may request more detail on the capabilities of the specific equipment (Appendix B) that might be used to accomplish their scientific objectives and/or items listed in the Bibliography (Appendix A, Section XII).

B. GROUND RESEARCH PROPOSAL

The ground research proposal should not exceed 20 pages in length, exclusive of appendices and supplementary material, and should be typed on 8-1/2 x 11 inch paper with a 10- or 12-point font.

Extensive appendices and ring-bound proposals are discouraged. Reprints and preprints of relevant work will be forwarded to the reviewers if submitted as attachments to the proposal.

The guidance in Appendix C, Section D regarding the content of renewal proposals is not applicable to this NRA.. Renewal proposals should not rely on references to previous proposals for any information required for a complete proposal. For renewal purposes see below (•7 Prior Period Of Support).

Fifteen copies of the proposal must be received at NASA Headquarters by May 15, 2000, 4:30 PM EDT to assure full consideration. Treatment of late proposals is described in Appendix C. Send proposals to the following address:

Dr. Mark C. Lee
NASA c/o InDyne, Inc.
Subject: NASA Research Proposal (NRA-00-HEDS-02)
300 D Street, S.W.
Washington, D.C. 20024
Telephone number for delivery services: (202) 479-2609

NASA can not receive deliveries on Saturdays, Sundays or federal holidays.

Ground research proposals submitted in response to this Announcement must be typewritten in English and contain at least the following elements (in addition to the required information given in Appendix C) in the format shown below, in the following order:

1. Form A (Solicited Proposal Application)
2. Form B (Proposal Executive Summary). The executive summary should succinctly convey, in broad terms, what it is the proposer wants to do, how the proposer plans to do it, why it is important, how it meets the requirements for microgravity relevance, a statement that this is a ground-based proposal, and if it is a scientific or a technology development proposal.
3. Form C (Budget For Entire Project Period Direct Costs Only)
4. Form D (Summary Proposal Budget - 1 copy for each year)
5. Table of Contents
6. Research Project Description containing the following elements:
    - Statement of the hypothesis, objective, and value of this research
    - Review of relevant research
    - A description of the proposed research
    - Microgravity Justification
    - A description of the proposed outreach and education activities
    - Management plan appropriate for the scope and size of the proposed project, describing the roles and responsibilities of the participants.
7. Prior Period of Support
    - **For follow-on proposals of ongoing MRD sponsored projects, a summary of the objective and accomplishments of the prior period of support, including citations to published papers derived from the existing tasks, must be included as part of the proposers justification for continued support.**
8. Appendices:
    - Supplementary budget information and budget explanations. The cost detail desired is explained below
    - Summary of current and pending support for the Principal Investigator and Co-Investigators from all other funding agencies.

- Complete current curriculum vita for the Principal and Co-Investigators, listing education, publications, and other relevant information necessary to assess the experience and capabilities of the senior participants.

9. **3.5 inch computer diskette containing electronic copy of Principal Investigator's name, address, complete project title, and executive summary**

Proposal Cost Detail Desired. Sufficient proposal cost detail and supporting information will facilitate a speedy evaluation and award. Dollar amounts proposed with no explanation (e.g., Equipment: $58,000, or Labor: $10,000) may cause delays in evaluation or award. The proposed costing information should be sufficiently detailed to allow the Government to identify cost elements for evaluation purposes. Generally, the Government will evaluate cost as to if it is reasonable, allowable, and appropriate. Enclose explanatory information, as needed. Each category should be explained. Offerors should exercise prudent judgment as the amount of detail necessary varies with the complexity of the proposal.

VI. FLIGHT RESEARCH PROPOSAL SUBMISSION INFORMATION

This section gives the requirements for submission of flight definition proposals in response to this announcement. A Principal Investigator who is responsible for all research activities must direct flight research proposals submitted under this announcement. The proposal may include one or more Co-Investigators as part of the science team. Proposals must address all the relevant selection criteria as described in Section XI and must format their proposal as described in this section. Additional general information for submission of proposals in response to NASA Research Announcements may be found in Appendix C.

A. FLIGHT RESEARCH LETTER OF INTENT [also referred to as Notice of Intent (NOI)]

Organizations planning to submit a flight research proposal in response to this NRA should notify NASA of their intent to propose by electronically sending a Letter of Intent (LOI) via the MRD Web Page:

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Alternatively, Letters of Intent may be submitted via e-mail to the following address: loi@hq.nasa.gov

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The Letter of Intent, which should not exceed two pages in length, must be typewritten in English and must include the following information:

- Principal investigator name, position, organization, address, telephone, fax, and e-mail address.
- A list of potential Co-Investigators (Co-I's), positions, and organizations.
- General scientific/technical objectives of the research.
- A statement identifying the proposal as being for flight definition.
- The equipment of interest listed in this NRA, if appropriate.

The Letter of Intent should be received at NASA Headquarters no later than March 13, 2000. The Letter of Intent is being requested for informational and planning purposes only, and is not binding on the signatories. Institutional authorizations are not required. The Letter of Intent allows NASA to better match expertise in the composition of peer review panels with the response from this solicitation. In the Letter of Intent, investigators may request more detail on the capabilities of the specific equipment (Appendix B) that might be used to accomplish their scientific objectives and/or items listed in the Bibliography (Appendix A, Section XII).

B. PROPOSAL

The proposal should not exceed 20 pages in length, exclusive of appendices and supplementary material, and should be typed on 8-1/2 x 11 inch paper with a 10- or 12-point font. Extensive appendices and ring-bound proposals are discouraged. Reprints and preprints of relevant work will be forwarded to the reviewers if submitted as attachments to the proposal.

The guidance in Appendix C, Section D regarding the content of renewal proposals is not applicable to this NRA. Renewal proposals should not rely on references to previous proposals for any information required for a complete proposal.

Fifteen copies of the proposal must be received at NASA Headquarters by May 15, 2000, 4:30 PM EDT to assure full consideration. Treatment of late proposals is described in Appendix C. Send proposals to the following address:

Dr. Mark C. Lee
NASA c/o InDyne, Inc.
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NASA can not receive deliveries on Saturdays, Sundays or federal holidays.

Proposals submitted in response to this Announcement must be typewritten in English and contain at least the following elements (in addition to the required information given in Appendix C) in the format shown below, in the following order:

1. Form A (Solicited Proposal Application)
2. Form B (Proposal Executive Summary). The executive summary should succinctly convey, in broad terms, what it is the proposer wants to do, how the proposer plans to do it, why it is important, how it meets the requirements for microgravity relevance, and state that this is a flight definition proposal.
3. Form C (Budget for the experiment through completion - one copy for investigator science support funding and one copy for instrument development funding. Assume funding will start at the beginning of 2001 and that the experiment will fly at the end of 2007.)
4. Form D (Summary Proposal Budget - one copy for each of the first four years -one copy for each of the two budget categories)
5. Table of Contents
6. Research Project Description containing the following elements:
    - Statement of the hypothesis, objective, and value of this research.
    - Review of relevant research.
    - Justification of the need for low gravity to meet the objectives of the experiment.
    - A description of the proposed research.
    - A description of the measurements and measurement techniques planned for use in space in order to satisfy the scientific objectives.
    - An estimate of the time profile of reduced-gravity levels needed for the experiment.
    - A description of the ground-based technology developments and scientific testing program that is required to determine the space flight experiment requirements.
    - Sufficient technical implementation detail to justify the total proposed budget.
    - A description of the proposed outreach and education activities

- Management plan appropriate for the scope and size of the proposed project, describing the roles and responsibilities of the participants.

7. Prior Period of Support
    - **For follow-on proposals of ongoing MRD sponsored projects, a summary of the objective and accomplishments of the prior period of support, including citations to published papers derived from the existing tasks, must be included as part of the proposers justification for continued support.**
8. Appendices:
    - Detailed budget information and budget explanations. The cost detail desired is explained below.
    - Summary of current and pending support for the Principal Investigator and Co-Investigators.
    - Complete current curriculum vita for the principal and Co-Investigators, listing education, publications, and other relevant information necessary to assess the experience and capabilities of the senior participants.
9. **3.5 inch computer diskette containing electronic copy of Principal Investigator's name, address, complete project title, and executive summary**

Proposal Cost Detail Desired. Sufficient proposal cost detail and supporting information will facilitate a speedy evaluation and award. Dollar amounts proposed with no explanation (e.g., Equipment: $58,000, or Labor: $10,000) may cause delays in evaluation or award. The proposed costing information should be sufficiently detailed to allow the Government to identify cost elements for evaluation purposes. Generally, the Government will evaluate cost as to reasonableness, allowability, and allocatability. Enclose explanatory information, as needed. Each category should be explained. Offerors should exercise prudent judgment as the amount of detail necessary varies with the complexity of the proposal. Due to their complexity, flight definition proposals are expected to contain more detailed cost information than ground proposal studies.

VII. GROUND AND FLIGHT RESEARCH PROPOSAL FUNDING

The total amount of funding for this program is subject to the annual NASA budget cycle. The Government's obligation to make awards is contingent upon the availability of appropriated funds from which payment for award purposes can be made and the receipt of proposals that the Government determines are acceptable for an award under this NRA.

For the purposes of budget planning, assume that the Microgravity Research Division will fund up to 7 flight experiment definition proposals at an average of $250,000 per year for the investigator science support portion. The instrument development budget portion for flight definition investigations will be allocated based on actual proposal needs. Approximately 30 - 50 ground-based study proposals will be funded, at an average of $100,000 per year, for up to 4 years with an interim peer review at the end of the third year. The initial fiscal year (FY) 2001 funding for all proposals will be adjusted, if required, to reflect partial fiscal year efforts. It is important that the proposer realistically forecast the projected spending timeline rather than merely assuming an equal amount (adjusted for inflation) of requirements for each year. The proposed budget should include researcher's salary, equipment, other expenses (publication costs, computing or workstation costs), burdens, overhead, and travel to science and NASA meetings. For flight investigations, roughly four meetings per year with NASA should be anticipated, though travel activity will vary over the development of the experiment. Ground investigators should plan one trip to a NASA workshop each year.

VIII. ADDITIONAL GUIDELINES APPLICABLE TO FOREIGN PROPOSALS AND PROPOSALS INCLUDING FOREIGN PARTICIPATION.

(1) NASA welcomes proposals from outside the U.S. However, foreign entities are generally not eligible for funding from NASA. Therefore, unless otherwise noted, proposals from foreign entities should not include a cost plan unless the proposal involves collaboration with a U.S. institution, in which case a cost plan for only the participation of the U.S. entity must be included. Proposals from foreign entities and proposals from U.S. entities that include foreign participation must be endorsed by the respective government agency or funding/sponsoring institution in the country from which the foreign entity is proposing. Such endorsement should indicate that the proposal merits careful consideration by NASA, and if the proposal is selected, sufficient funds will be made available to undertake the activity as proposed.

(2) All foreign proposals must be typewritten in English and comply with all other submission requirements stated in the NRA. All foreign proposals will undergo the same evaluation and selection process as those originating in the U.S. All proposals must be received before the established closing date. Those received after the closing date will be treated in accordance paragraph (g) of this provision. Foreign sponsors may, in exceptional situations, forward a proposal without endorsement if the endorsement is not possible before the announced closing date. In such cases, the NASA sponsoring office should be advised when a decision on endorsement can be expected.

(3) Successful and unsuccessful foreign entities will be contacted directly by the NASA sponsoring office. Copies of these letters will be sent to the foreign sponsor. Should a foreign proposal or a U.S. proposal with foreign participation be selected, NASA's Office of External Relations will arrange with the foreign sponsor for the proposed participation on a no-exchange-of-funds basis, in which NASA and the foreign sponsor will each bear the cost of discharging their respective responsibilities.

(4) Depending on the nature and extent of the proposed cooperation, these arrangements may entail:

(i) An exchange of letters between NASA and the foreign sponsor; or

(ii) A formal Agency-to-Agency Memorandum of Understanding (MOU).

IX. CANCELLATION OF NRA.

NASA reserves the right to make no awards under this NRA and to cancel this NRA. NASA assumes no liability for canceling the NRA or for anyone's failure to receive actual notice of cancellation.

X. EXPORT CONTROL GUIDELINES APPLICABLE TO FOREIGN PROPOSALS AND PROPOSALS INCLUDING FOREIGN PARTICIPATION.

Foreign proposals and proposals including foreign participation must include a section discussing compliance with U.S. export laws and regulations, e.g., 22 CFR Parts 120-130 and 15 CFR Parts 730-774, as applicable to the circumstances surrounding the particular foreign participation. The discussion must describe in detail the proposed foreign participation and is to include, but not be limited to, whether or not the foreign participation may require the prospective proposer to obtain the prior approval of the Department of State or the Department of Commerce via a technical assistance agreement or an export license, or whether a license exemption/exception may apply. If prior approvals via licenses are necessary, discuss whether the license has been applied for or if not, the projected timing of the application and any implications for the schedule. Information regarding U.S. export regulations is available at http://www.pmdtc.org and http://www.bxa.doc..gov. Proposers are advised that under U.S. law and regulations, spacecraft and their specifically designed, modified, or configured systems, components, and parts are generally considered "Defense Articles" on the United States Munitions List and subject to the provisions of the International Traffic in Arms Regulations (ITAR), 22 CFR Parts 120-130.

XI. RESEARCH PROPOSAL EVALUATION AND SELECTION

A. RESEARCH PROPOSAL EVALUATION PROCESS.

The evaluation process for this NRA will begin with a scientific and technical peer review of the submitted proposals. NASA will also evaluate the proposed budget. For flight definition proposals, NASA will also conduct engineering and management reviews to establish feasibility of the planned implementation, to review risk mitigation plans, to evaluate the experience of the implementing organization, and to review the budget. The programmatic objectives of this NRA, as discussed in the introduction to this Appendix, will be applied by NASA to enhance program breadth, balance, and diversity. Upon completion of deliberations, offerors will be notified regarding proposal selection or rejection. Offerors whose proposals are declined will have the opportunity of a verbal debriefing with a NASA representative regarding the reasons for this decision. Additional information on the evaluation and selection process is given in Appendix C.

B. RESEARCH PROPOSAL EVALUATION FACTORS.

The principal elements considered in the evaluation of proposals solicited by this NRA are relevance to NASA's objectives, intrinsic merit, and cost. Of these, intrinsic merit has the greatest weight, followed by relevance to NASA's objectives, of slightly lesser weight. Both of these elements have greater weight than cost. Evaluation of the intrinsic merit of the proposal includes consideration of the following factors, in descending order of importance:

1. Overall scientific or technical merit, including evidence of unique or innovative methods, approaches, or concepts, and the potential for new discoveries or understanding, or delivery of new technologies/products;
2. Qualifications, capabilities, and experience of the proposed Principal Investigator, team leader, or key personnel who are critical in achieving the proposal objectives;
3. Institutional resources and experience that are critical in achieving the proposal objectives;
4. Proposed plan for education and public outreach activities. Examples include such items as involvement of students in the research activities, technology transfer plans, public information programs that will inform the general public of the benefits being gained from the research, and/or plans for incorporation of scientific results obtained into educational curricula.

Evaluation of the cost of a proposed effort includes consideration of the realism and reasonableness of the proposed cost, and the relationship of the proposed cost to available funds.

The scientific peer review panel will assign each proposal a numerical merit score from 1 (worst) to 9 (best) based on the above factors. The score assigned by the peer review panel will not be affected by the cost of the proposed work nor will it reflect the programmatic relevance of the proposed work to NASA. However, the panel will be asked to include in their critique of each proposal any comments they may have concerning the proposal's budget and relevance to NASA. For flight proposals, the engineering and management panel will evaluate the feasibility and complexity of accomplishing each investigation along with an estimate of total cost for flight hardware development. NASA will take these assessments into consideration in making the final selection of experiments that will be considered for flight definition.

Evaluation of a proposal's relevance to NASA's objectives includes the consideration of the potential contribution of the effort to NASA's mission.

The following questions should be kept in mind by proposers when addressing the relevance to NASA's scientific and programmatic objectives:

1. Is the space environment of fundamental importance to the proposed study, such as in unmasking

effects hidden under normal gravity conditions, or in using the gravity level as an added independent parameter, or in providing access to boundary conditions not available on the Earth?

2. Do the issues addressed by the research have the potential to close major gaps in the understanding of fundamental physics?
3. Is there potential for major discovery or elucidation of previously unknown phenomena?
4. Is the project likely to have significant benefits/applications to ground-based as well as space-based operations involving fundamental physics?
5. Are the results likely to be broadly useful, leading to further theoretical or experimental studies?
6. Is the proposal bold, or incremental in nature from what has been done before?
7. Is the project technologically feasible, without requirements for substantial new technological advances?
8. How will this project stimulate research and education in the fundamental physics area?
9. How does the projected cost/benefit ratio compare with other projects competing for the same resources?
10. What is the potential of this project in terms of stimulating future technological "spin-offs".

XII. BIBLIOGRAPHY

Background materials are available to NRA proposers upon written request to:

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Technical Adivisor, Fundamental Physics
MS 233-200
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354- 9255
ulf.israelsson@jpl.nasa.gov

Documents and Web Sites that may provide useful information to proposers are listed below:

1. Microgravity Science and Applications Division, on the World Wide Web: http://microgravity.msad.hq.nasa.gov

2. Microgravity Science and Applications Apparatus and Facilities, NASA Marshall Space Flight Center.

3. STS Investigators' Guide, NASA Marshall Space Flight Center.

4. Microgravity Science and Applications Program Tasks and Bibliography, NASA Technical Memorandum 4735, 1996, https://peer1.idi.usra.edu/taskbook/taskbook.html.

5. Low Temperature Platform Briefing Document, JPL D-11781

6. The Proceedings of the NASA/JPL 1994 Microgravity Low Temperature Physics Workshop, JPL D-11775

7. The Proceedings of the NASA/JPL 1996 Microgravity Low Temperature Physics Workshop, JPL D-13845

8. The Proceedings of the NASA/JPL 1998 Microgravity Fundamental Physics Workshop, JPL D-18442

9. Microgravity Research Facilities and Fluid Physics Flight Experiments, Space Experiment Division, NASA Glenn Research Center, on the World Wide Web: http://zeta.lerc.nasa.gov

10. Fundamental Physics in Space Roadmap, JPL 400-808, April 1999. Viewgraphs available at http://www.jpl.nasa.gov/physics/roadmap

11. Details about the capabilities of the Low Temperature Microgravity Physics Facility can be found on http:/ltmpf.jpl.nasa.gov/

APPENDIX B
NRA-00-HEDS-02

HARDWARE AND FACILITY DESCRIPTIONS

The Microgravity Research Division (MRD) is pursuing a program for International Space Station (ISS) payloads that can be configured (or reconfigured) to accommodate multiple users. This evolutionary program is expected to meet the science requirements of increasingly sophisticated microgravity investigations and to permit the eventual development of experiment payload technologies for research throughout the era of the ISS.

I. CURRENT AND PLANNED FLIGHT HARDWARE

The evolving focus of the MRD flight program emphasizes the development of modular payloads that can be configured (or easily reconfigured) to accommodate multiple users. In anticipation of this evolution in experimental hardware, NASA has started development of hardware capabilities suitable for some of the research described in Appendix A. This hardware will be available for flights in 2004 and beyond. The experimental apparatus described in this section are under development for flight on a series of missions to the International Space Station. Availability of the hardware described here, with or without modification, is contingent upon the allocation of NASA resources, and cannot be guaranteed at this time.

More detailed descriptions of the current and planned flight hardware may be requested in the Letter of Intent described in Appendix A, Section VI.

A. LOW TEMPERATURE MICROGRAVITY PHYSICS FACILITY (LTMPF)

The Low Temperature Microgravity Physics Facility is a complete low temperature laboratory to be attached to the Exposed Facility of the Japanese Experiment Module on the International Space Station (ISS). There will be two identical facilities, each weighs about 500Kg and each can support two experiments operating simultaneously. A superfluid helium dewar maintains a base temperature pre-selected at between 1.6 K to 2.0 K for a period of approximately five months.

The dewar insert (the instrument) is configured to accommodate two experiments. Typically it consists of two sets of thermal-mechanical platforms called probes. Attached to each probe are the experiment unique cells and sensors.. Each probe can have several stages of isolation platforms with separate temperature regulations on each stage to provide the maximum temperature stability. The total volume for both probes and experiment hardware occupies a cylindrical volume of 19 cm in diameter and 70 cm long. The total allocated weight for both sets of experiment hardware attached to the probes (but excluding the probe mass) is 12 Kg or less. Electronics are built on the modular VME chassis with up to 42 slots for standard or custom-built electronic boards that can be reconfigured for each flight. Ultra high-resolution temperature and pressure sensors have been developed based on SQUID (Super-conducting Quantum Interference Devices) magnetometers. The LTMPF accommodates up to 12 SQUIDs shared between the two experiments. The high-resolution thermometers have demonstrated sub-nano-Kelvin temperature resolution in past space experiments. Other existing measurement techniques include resistance thermometers, precision heaters, capacitance bridges, precision clocks and frequency counters, modular gas handling systems, and optical access capability. An onboard flight computer controls all facility and instrument electronics, all ISS interfaces, command, telemetry, and data storage during on-orbit operations.

Most LTMPF experiments are sensitive to random vibrations, charged particles, and stray magnetic fields. The level of random vibrations at low frequency (< 0.1 Hz) is several μg rms. A passive vibration isolation system attenuates higher frequency (> 1 Hz) vibration inputs from the ISS to below 500 μg rms. Several layers of magnetic shielding are built into the instrument probe to protect the experiments from on-orbit variations in the magnetic field environment. Vibration and radiation monitors will provide experimenters with near real-time data. The main concern from charged particles is the heating they cause on the experimental cells and sensors. The estimated heating levels range from a fraction of a pico-watt per gram of material to many orders of magnitude higher heating levels depending on the charged particle environment at that particular orbit location.

The responsibility for developing and testing the experiment hardware and software rests on the principal investigator. The PI may choose to delegate this responsibility to an experienced contractor including JPL. In addition to general management and science support, JPL will also be responsible for the final integration of experiment hardware to the facility and the engineering activities thereafter. We expect the first launch will be on-board a Japanese H-IIA rocket in June, 2004. Subsequent launches and retrievals will be more likely on the Shuttle. Once on ISS, the experiments simultaneously take data for approximately five months. After cryogen depletion, LTMPF may continue to monitor environments on board the ISS while it awaits return by the Shuttle. Upon return to Earth, the experiments undergo de-integration and some post-flight testing. The facility and perhaps some of the experiment hardware are then refurbished for the next set of experiments. Each facility is designed to survive five cycles of testing, launch and landing. Taking turns to launch one facility approximately every 16 months will provide for up to fifteen years of service to experiments that demand an environment of long duration microgravity at low temperature.

B. LCAP HARDWARE

There are currently two LCAP flight projects under development by NASA.. These are the Primary Atomic Reference Clock in Space (PARCS), a Cesium atomic clock scheduled to be launched in 2004, and the Rubidium Atomic Clock Experiment (RACE), a Rubidium atomic clock scheduled to be launched in 2006. Each of these experiments will feature laser-cooled atomic clocks, and will carry out a variety of tests of general relativity theory. To support these and future flight experiments, a variety of technologies will be developed to enable space flight experiments involving Cs and Rb. The goal is to provide investigators with much of the same capability in space that they currently have in ground-based laser cooling experiments. A number of specific hardware packages are currently under development or are planned for development and are listed below as typical examples of LCAP experiment specific hardware.

<u>Lasers:</u> NASA is currently developing injection-locked laser systems capable of producing several hundred milliwatts of tunable, frequency stabilized light suitable for a typical Magneto-Optical Trap (MOT) or molasses experiment. These are designed to be robust enough to survive a space shuttle launch and operate for up to a year of stand-alone operation. Such laser systems are being developed at both the cesium and rubidium wavelengths. These technologies should be applicable to a wide variety of future experiments employing these atomic species.

<u>Vacuum systems</u>: Ultra-High Vacuum (UHV) systems employing a combination of ion pump and getter technologies will be developed to provide vacuum capability below 10^{-10} torr.

<u>Cold atom sources</u> NASA is currently developing capabilities to collect atoms in a vapor cell molasses or magneto-optical trap (MOT), cool them to a temperature below 2 μK and then launch them with a moving molasses into an UHV region. In addition to this capability, we plan to develop compact atomic beam sources, such as a two-dimensional MOT or a low velocity intense source.. These would be suitable for loading a UHV MOT with a very high atom number, such as is required for a a Bose-Einstein Condensation experiment.

<u>Compact Magnetic traps</u>: In addition to MOTs and optical molasses, NASA will also develop compact magnetic traps of the Ioffe-Pritchard type. These traps are suitable for BEC experiments. These will have a power consumption low enough to be compatible with an ISS - EXPRESS rack.

<u>Raman-cooling laser systems:</u> A laser system suitable for driving Raman transitions in cesium is a planned future development. Such a laser could be used for a Raman-cooling experiment or for an atom interferometer.

C. FAST ALTERNATIVE CRYOGENIC EXPERIMENT TESTBED (FACET)

A proof of concept demonstration of FACET prototype hardware for a Hitchhiker Siderail payload for the space shuttle was recently completed successfully at the Jet Propulsion Laboratory. Depending on budget availability, NASA may decide to develop a flight version of FACET and make it available to researchers for short duration Shuttle experiments. This facility will provide frequent low-cost access to space for short duration cryogenic fundamental physics experiments as rapid response payloads (requiring only 9 months from completion of laboratory testing to launch). A hybrid solid neon - superfluid helium cryostat will provide on-orbit experimentation time at a selectable helium bath temperature of 1.8 to 2.05 Kelvin for the full duration of even the longest shuttle missions (16 days). Each cryogenic instrument insert may weigh up to 15 kg and is constrained in size to a cylinder 16.5 cm diameter by 30 cm long. Provisions for instrument power, electronic and software control, near real time telemetry and command, radiation and acceleration environment monitors and telescience operation are included. The instrument control and readout electronics utilizes a Versa Modular European (VME) bus architecture. This modular approach enhances the opportunity for investigation specific circuitry. In addition, a Digital Signal Processor (DSP) interface between the VME bus and the sensor interface circuits is used. This approach provides scalable processing power, including programmable signal processing and control at the board level. The facility will provide a DC acceleration environment of about 10^{-6} g during planned microgravity periods and 10^{-4} g at all other times. Flight opportunities for the FACET facility occur roughly four times each year. The first flight could occur within 3 1/2 years after authorization to proceed. JPL will support experimenters with the flight instrument integration and test with the facility, environmental test, delivery to KSC, the launch campaign and planning and the conduct of flight operations. JPL will also support experimenters with the flight instrument build if requested.

D. GLOVEBOX

The overall philosophy of the Glovebox program is to provide the ability to conduct smaller, less complex science experiments or technology demonstrations in a space environment in a faster, better, and cheaper manner. Experiments developed for the Glovebox are expected to be relatively small and self-contained yet can be of a sophisticated nature using state of the art diagnostics. Various services are available in the Gloveboxes including power, video, still photography, a laptop computer for experiment control and data acquisition, and cleaning supplies. In general these experiments are less automated and require significant crew involvement in their operation and in the scientific decision-making process.

The ISS Microgravity Science Glovebox (MSG) is under development by the European Space Agency, and will be available for use soon after the deployment of the US Laboratory Module of the ISS. The MSG will have a larger work area than the Shuttle version to allow larger size and mass experiments to be conducted inside the Glovebox. The MSG will provide up to 1000 watts of experiment power, a vent connection, a nitrogen connection, an airlock, illumination, color and black and white video cameras and recorders for viewing, recording, or down-linking, and miscellaneous tools and cleaning supplies. More information is available on request.

E. EXPRESS RACK FACILITY (ERF)

The ERF is a multi-user facility that provides simplified, standard payload interfaces for Space Station payload integration thus reducing development time for the experiment developer. The ERF is envisioned to have greater mass, volume, power and data capabilities than the MSG. It can accommodate existing payloads and add more experiments to the user community. There are two ERF configurations. One is the 8 mid-deck lockers and 2 Standard Interface Rack (SIR) drawers. The other configuration is 15 SIR drawers.

The ERF can provide accommodations for small and medium sized payloads, provide simple standard hardware and software interfaces, and also provide for simple and streamlined integration. The ERF hardware data is displayed on-orbit and down-linked both in real-time and non-real-time. NASA may use the ERF to accommodate the planned PARCS and RACE projects. The ERF may be suitable also for future experiments in Laser Cooling and Atomic Physics.

F. FLUIDS INTEGRATED RACK (FIR) EXPERIMENT SPECIFIC HARDWARE

The FIR features the capability to remove and replace different PI specific experiment packages. The PI experiment specific package(s) may consist of a single self-contained unit and/or several separate components. The PI hardware will typically be a unique design, but may re-use hardware and designs from previous experiments. A set of similar experiments investigating common phenomena and/or using similar diagnostics may permit the development of a “mini-facility” that can accommodate multiple PIs to significantly lower overall PI development costs. The experiment package will typically consist of the sample test cell(s), precision optical diagnostic instrumentation (shearing interferometry, schlieren, surface profilometry, etc.) that interface with FIR services, and any support equipment such as injection & mixing devices, motors, critical temperature hardware, magnetic field generation not provided by the FIR.

G. UKRAINIAN CRYOGENIC FACILITY FOR THE ISS

The Ukrainian Cryogenic Facility (UCF) is under development for potential flight aboard the International Space Station (ISS) as a part of the Ukrainian Scientific Module (USM) payload. The UCF is a new facility currently being designed at Special Research & Development Bureau for Cryogenic Engineering of Institute for Low Temperature Physics & Engineering of National Academy of Sciences of Ukraine in Kharkov. Its planned use is to study a wide range of fundamental problems in low temperature physics in space. The UCF first flight will carry the Helium Rotating Unit - Boiling In Microgravity (HERUBIM) experiment to investigate the effects of a free fall environment on liquid helium pool boiling. A 2003 launch readiness date is being targeted for the first flight.

The UCF main component is a cryostat mounted outside the USM body together with electronic support equipment on a rotating platform. Rotation of the cryostat will provide a controlled magnitude and direction of the acceleration vector at the experimental cell location in the range from 10^{-4} to 10^{-2} g, which is more than the residual accelerations level of 10^{-5} g. A three-axial transducer will monitor the local acceleration. The cryostat contains 100 liters of liquid helium and a nominal experiment lifetime is 30 days. The HERUBIM Experiment involves the use of two cryostats, one of which is flown in space. The pressure of the helium is held at saturated vapor pressure and the liquid temperature can be varied from 1.8 to 4.5 K. The experimental cell is mounted inside the cryostat "optical finger" volume of 0.15 m inner diameter and 0.18 m height. The mass of an experimental cell should not exceed 5 kg. The cryostat "optical finger" has four cold optical windows and an array of four digital video cameras, each with magnification optics and illumination source to image the single vapor bubbles and moving boundaries between nucleate and film boiling areas on the flat heating surfaces. Video control system delivers the video signal to a portable video recorder. Application of heat to the experimental cell is accomplished by a heat flux source. It can provide step by step increase and decrease of the heat flux from 0.3 mW to 5 W. The heat flux can be delivered to two separate heaters simultaneously.

The UCF instrumentation consists of temperature measurements of the bulk liquid and of the boiling surface, pressure measurement, and heater power measurement. Power up to 100 W can be provided to the UCF equipment via a protected 28 V DC source. A laptop computer will provide UCF operation and experiment program control with limited options for crew commanding and for control from the Earth (quasi real time telescience). The UCF equipment can provide both on-orbit recording of video and measuring experimental data, onboard data storage and partial transmission of data to Earth in near real time.

The UCF can accommodate multiple users who find it necessary to carry out experiments in liquid helium, and who find it important to ensure well known constant magnitude and direction acceleration levels in the range from 10-4 to 10-2 g, along with the possibility for optical studies of the sample.

H. DISPOSITIF POUR L'ETUDE DE LA CROISSANCE ET DES LIQUIDES CRITIQUES (DECLIC)

DECLIC is a new, modular, multi-user facility currently being designed and built by the French Space Agency, CNES for use aboard the International Space Station, initially in the US Laboratory followed by the Japanese Experiment Module, the Columbus Orbital Facility or the Russian module. The facility is being designed to conduct microgravity investigations in critical phenomena and directional solidification of transparent alloys.

Specifically, DECLIC will accommodate chemical-physical studies of supercritical pure fluids with a critical temperature lower than 100°C and a critical pressure lower than 100 bar (such as CO_2, SF_6 and Xe), and supercritical pure fluids and solutions with a critical temperature lower than 600°C and a critical pressure lower than 500 bar (such as H_2O and aqueous solutions). It will also accommodate microgravity investigations in morphological stability at the solid/liquid interface during crystal growth in transparent alloys. In addition, investigations in condensed matter physics requiring a long-term microgravity environment can also take advantage of the capabilities offered by DECLIC.

DECLIC is the follow-on to the ALICE-2 facility, still onboard the Russian MIR space station, but will accommodate wider classes of experiments. The facility provides advanced optical diagnostics, including wide field imaging, microscopy, interferometry and small angle light scattering as well as highly accurate measurements of thermophysical parameters (pressure, temperature). All experiments can be conducted within a very stable and accurately controlled thermal environment. Operation of the facility is via quasi real-time telescience. More detailed information about DECLIC and its capabilities can be obtained at the CNES web site: http://www.cnes.fr/espace_pro/declic/declic.html

II. <u>GROUND-BASED FACILITIES</u>

Investigators often need to conduct reduced gravity experiments in ground-based facilities during the experiment definition and technology development phases. The NASA ground-based reduced gravity research facilities that support the MRD fluids program include two drop towers at the Glenn Research Center (GRC) and parabolic flight research aircraft.

A. 2.2-SECOND DROP TOWER

The 2.2 Second Drop Tower is a heavily utilized reduced gravity facility at the Glenn Research Center that plays a key role in the support of Microgravity Science. It routinely supports over 1000 test drops per year (the daily test schedule allows up to 12 drops). The facility consists of a shop for experiment buildup, integration and testing; several small laboratories for experiment preparation and normal gravity testing; electronics support rooms and an eight story tower in which the drop area is located.

The Drop Tower at GRC provides 2.2 second of low gravity test time for experiment packages with payload weights up to 139 kg. Rectangular experiment packages are dropped under normal atmospheric conditions from a height of 79 ft. Air drag on an experiment is minimized by enclosing it in a drag shield. A DC gravitational acceleration level of less than 10^{-4} g is obtained during the drop as the experiment package falls freely within the drag shield. The only external force acting on the falling experiment package is the air drag associated with the relative motion of the package within the enclosure of the drag shield. A drop is terminated when the drag shield and experiment assembly impacts an air bag. The deceleration levels at impact have peak values of 15 to 30 g.

High-speed motion picture cameras as well as video cameras can acquire data. Video signals are transmitted to remote video recorders via a fiber optic cable that is dropped with the experiment. Onboard data acquisition and control systems also record data supplied by instrumentation such as thermocouples, pressure transducers, and flowmeters.

B. 5.18-SECOND ZERO-GRAVITY FACILITY

The 5.18-second Zero-Gravity Facility at the Glenn Research Center has a 132 meter free fall distance in a drop chamber which is evacuated by a series of pumpdown procedures to a final pressure of 1 Pa. Experiments with hardware weighing up to 300 kilograms are mounted in a one meter diameter by 3.4 meter high drop bus. A DC gravitational acceleration of less than 10^{-5} g is obtained. At the end of the drop, the bus is decelerated in a 6.1-meter deep container filled with small pellets of expanded polystyrene. The deceleration rate ramps up to 65 g in 150 milliseconds.. Visual data is acquired through the use of on-board, high-speed motion picture cameras and 8-mm video recorders. Also, other data such as pressures and temperatures are recorded on board with various data acquisition systems. Deceleration data are transmitted to a control room by a telemetry system. Due to the complexity of drop chamber operations and time required for pump-down of the drop chamber, only one or two tests are performed per day.

C. PARABOLIC FLIGHT RESEARCH AIRCRAFT

The parabolic research aircraft can provide up to 40 periods of low gravity for up to 25-second intervals each during one flight. The aircraft can accommodate a variety of experiments of different sizes and is often used to refine space flight experiment equipment and techniques and to train crew members in experiment procedures, thus giving investigators and crew members valuable experience working in a weightless environment. The aircraft creates a low gravity environment by flying a parabolic trajectory. Gravity levels twice those of normal gravity occur during the initial and final portions of the trajectory, while the brief pushover at the top of the parabola produces less than one percent of Earth's gravity (10^{-2} g). The interior bay dimensions are approximately 3 meters wide and 2 meters high by 16 meters long. Several experiments, including a combination of attached and free-floated hardware (which can provide effective gravity levels of 10^{-3} g for periods up to 10 seconds) can be integrated in a single flight. Both 28 VDC and 100/115 VAC power are available. Instrumentation and data collection capabilities must be contained in the experiment packages.

III. **MICROGRAVITY FUNDAMENTAL PHYSICS TECHNOLOGY**

NASA has adapted or developed a number of advanced techniques and technologies for microgravity fundamental physics research. Some of these techniques, such as high-resolution thermometry, SQUID readouts, and advanced thermal control systems, have already been successfully used in flight. Information about these technologies is available upon request.

APPENDIX C
NRA-00-HEDS-02

INSTRUCTIONS FOR RESPONDING TO NASA RESEARCH ANNOUNCEMENTS

(SEPTEMBER 1999)

A. General.

(1) Proposals received in response to a NASA Research Announcement (NRA) will be used only for evaluation purposes. NASA does not allow a proposal, the contents of which are not available without restriction from another source, or any unique ideas submitted in response to an NRA to be used as the basis of a solicitation or in negotiation with other organizations, nor is a pre-award synopsis published for individual proposals.

(2) A solicited proposal that results in a NASA award becomes part of the record of that transaction and may be available to the public on specific request; however, information or material that NASA and the awardee mutually agree to be of a privileged nature will be held in confidence to the extent permitted by law, including the Freedom of Information Act.

(3) NRAs contain programmatic information and certain requirements which apply only to proposals prepared in response to that particular announcement. These instructions contain the general proposal preparation information which applies to responses to all NRAs.

(4) A contract, grant, cooperative agreement, or other agreement may be used to accomplish an effort funded in response to an NRA. NASA will determine the appropriate instrument. Contracts resulting from NRAs are subject to the Federal Acquisition Regulation and the NASA FAR Supplement. Any resultant grants or cooperative agreements will be awarded and administered in accordance with the NASA Grant and Cooperative Agreement Handbook (NPG 5800.1).

(5) NASA does not have mandatory forms or formats for responses to NRAs; however, it is requested that proposals conform to the guidelines in these instructions. NASA may accept proposals without discussion; hence, proposals should initially be as complete as possible and be submitted on the proposers' most favorable terms.

(6) To be considered for award, a submission must, at a minimum, present a specific project within the areas delineated by the NRA; contain sufficient technical and cost information to permit a meaningful evaluation; be signed by an official authorized to legally bind the submitting organization; not merely offer to perform standard services or to just provide computer facilities or services; and not significantly duplicate a more specific current or pending NASA solicitation.

B. NRA-Specific Items. Several proposal submission items appear in the NRA itself: the unique NRA identifier; when to submit proposals; where to send proposals; number of copies required; and sources for more information. Items included in these instructions may be supplemented by the NRA.

C. Proposal Content. The following information is needed to permit consideration in an objective manner. NRAs will generally specify topics for which additional information or greater detail is desirable. Each proposal copy shall contain all submitted material, including a copy of the transmittal letter if it contains substantive information.

(1) ***Transmittal Letter or Prefatory Material***.

(i) The legal name and address of the organization and specific division or campus identification if part of a larger organization;

(ii) A brief, scientifically valid project title intelligible to a scientifically literate reader and suitable for use in the public press;

(iii) Type of organization: e.g., profit, nonprofit, educational, small business, minority, women-owned, etc.;

(iv) Name and telephone number of the principal investigator and business personnel who may be contacted during evaluation or negotiation;

(v) Identification of other organizations that are currently evaluating a proposal for the same efforts;

(vi) Identification of the NRA, by number and title, to which the proposal is responding;

(vii) Dollar amount requested, desired starting date, and duration of project;

(viii) Date of submission; and

(ix) Signature of a responsible official or authorized representative of the organization, or any other person authorized to legally bind the organization (unless the signature appears on the proposal itself).

(2) ***Restriction on Use and Disclosure of Proposal Information***.. Information contained in proposals is used for evaluation purposes only. Offerors or quoters should, in order to maximize protection of trade secrets or other information that is confidential or privileged, place the following notice on the title page of the proposal and specify the information subject to the notice by inserting an appropriate identification in the notice. In any event, information contained in proposals will be protected to the extent permitted by law, but NASA assumes no liability for use and disclosure of information not made subject to the notice.

Notice

Restriction on Use and Disclosure of Proposal Information

The information (data) contained in [insert page numbers or other identification] of this proposal constitutes a trade secret and/or information that is commercial or financial and confidential or privileged. It is furnished to the Government in confidence with the understanding that it will not, without permission of the offeror, be used or disclosed other than for evaluation purposes; provided, however, that in the event a contract (or other agreement) is awarded on the basis of this proposal the Government shall have the right to use and disclose this information (data) to the extent provided in the contract (or other agreement). This restriction does not limit the Government's right to use or disclose this information (data) if obtained from another source without restriction.

(3) ***Abstract***. Include a concise (200-300 word if not otherwise specified in the NRA) abstract describing the objective and the method of approach.

(4) ***Project Description***.

(i) The main body of the proposal shall be a detailed statement of the work to be undertaken and should include objectives and expected significance; relation to the present state of knowledge; and relation to previous work done on the project and to related work in progress elsewhere. The statement should outline the plan of work, including the broad design of experiments to be undertaken and a description of experimental methods and procedures. The project description should address the evaluation factors in these instructions and any specific factors in the NRA. Any substantial collaboration with individuals not referred to in the budget or use of consultants should be described. Subcontracting significant portions of a research project is discouraged.

(ii) When it is expected that the effort will require more than one year, the proposal should cover the complete project to the extent that it can be reasonably anticipated. Principal emphasis should be on the first year of work, and the description should distinguish clearly between the first year's work and work planned for subsequent years.

(5) ***Management Approach***.. For large or complex efforts involving interactions among numerous individuals or other organizations, plans for distribution of responsibilities and arrangements for ensuring a coordinated effort should be described.

(6) ***Personnel***.. The principal investigator is responsible for supervision of the work and participates in the conduct of the research regardless of whether or not compensated under the award. A short biographical sketch of the principal investigator, a list of principal publications and any exceptional qualifications should be included. Omit social security number and other personal items which do not merit consideration in evaluation of the proposal. Give similar biographical information on other senior professional personnel who will be directly associated with the project. Give the names and titles of any other scientists and technical personnel associated substantially with the project in an advisory capacity. Universities should list the approximate number of students or other assistants, together with information as to their level of academic attainment. Any special industry-university cooperative arrangements should be described.

(7) ***Facilities and Equipment.***

(i) Describe available facilities and major items of equipment especially adapted or suited to the proposed project, and any additional major equipment that will be required. Identify any Government-owned facilities, industrial plant equipment, or special tooling that are proposed for use. Include evidence of its availability and the cognizant Government points of contact.

(ii) Before requesting a major item of capital equipment, the proposer should determine if sharing or loan of equipment already within the organization is a feasible alternative. Where such arrangements cannot be made, the proposal should so state. The need for items that typically can be used for research and non-research purposes should be explained.

(8) ***Proposed Costs (U.S. Proposals Only).***

(i) Proposals should contain cost and technical parts in one volume: do not use separate "confidential" salary pages. As applicable, include separate cost estimates for salaries and wages; fringe benefits; equipment; expendable materials and supplies; services; domestic and foreign travel; ADP expenses; publication or page charges; consultants; subcontracts; other miscellaneous identifiable direct costs; and indirect costs. List salaries and wages in appropriate organizational categories (e.g., principal investigator, other scientific and engineering professionals, graduate students, research assistants, and technicians and other non-professional personnel). Estimate all staffing data in terms of staff-months or fractions of full-time.

(ii) Explanatory notes should accompany the cost proposal to provide identification and estimated cost of major capital equipment items to be acquired; purpose and estimated number and lengths of trips planned; basis for indirect cost computation (including date of most recent negotiation and cognizant agency); and clarification of other items in the cost proposal that are not self-evident. List estimated expenses as yearly requirements by major work phases.

(iii) Allowable costs are governed by FAR Part 31 and the NASA FAR Supplement Part 1831 (and OMB Circulars A-21 for educational institutions and A-122 for nonprofit organizations).

(iv) Use of NASA funds--NASA funding may not be used for foreign research efforts at any level, whether as a collaborator or a subcontract. The direct purchase of supplies and/or services, which do not constitute research, from non-U.S. sources by U.S. award recipients is permitted. Additionally, in accordance with the National Space Transportation Policy, use of a non-U.S.. manufactured launch vehicle is permitted only on a no-exchange-of-funds basis.

(9) ***Security.*** Proposals should not contain security classified material. If the research requires access to or may generate security classified information, the submitter will be required to comply with Government security regulations.

(10) ***Current Support.*** For other current projects being conducted by the principal investigator, provide title of project, sponsoring agency, and ending date.

(11) ***Special Matters***.

(i) Include any required statements of environmental impact of the research, human subject or animal care provisions, conflict of interest, or on such other topics as may be required by the nature of the effort and current statutes, executive orders, or other current Government-wide guidelines.

(ii) Proposers should include a brief description of the organization, its facilities, and previous work experience in the field of the proposal. Identify the cognizant Government audit agency, inspection agency, and administrative contracting officer, when applicable.

D. Renewal Proposals

(1) Renewal proposals for existing awards will be considered in the same manner as proposals for new endeavors. A renewal proposal should not repeat all of the information that was in the original proposal. The renewal proposal should refer to its predecessor, update the parts that are no longer current, and indicate what elements of the research are expected to be covered during the period for which support is desired. A description of any significant findings since the most recent progress report should be included. The renewal proposal should treat, in reasonable detail, the plans for the next period, contain a cost estimate, and otherwise adhere to these instructions.

(2) NASA may renew an effort either through amendment of an existing contract or by a new award.

E. Length.. Unless otherwise specified in the NRA, effort should be made to keep proposals as brief as possible, concentrating on substantive material. Few proposals need exceed 15-20 pages. Necessary detailed information, such as reprints, should be included as attachments. A complete set of attachments is necessary for each copy of the proposal. As proposals are not returned, avoid use of "one-of-a-kind" attachments.

F. Joint Proposals.

(1) Where multiple organizations are involved, the proposal may be submitted by only one of them. It should clearly describe the role to be played by the other organizations and indicate the legal and managerial arrangements contemplated. In other instances, simultaneous submission of related proposals from each organization might be appropriate, in which case parallel awards would be made.

(2) Where a project of a cooperative nature with NASA is contemplated, describe the contributions expected from any participating NASA investigator and agency facilities or equipment which may be required. The proposal must be confined only to that which the proposing organization can commit itself. "Joint" proposals which specify the internal arrangements NASA will actually make are not acceptable as a means of establishing an agency commitment.

G. Late Proposals. Proposals or proposal modifications received after the latest date specified for receipt may be considered if a significant reduction in cost to the Government is probable or if there are significant technical advantages, as compared with proposals previously received.

H. Withdrawal. Proposals may be withdrawn by the proposer at any time before award. Offerors are requested to notify NASA if the proposal is funded by another organization or of other changed circumstances which dictate termination of evaluation.

I. Evaluation Factors.

(1) Unless otherwise specified in the NRA, the principal elements (of approximately equal weight) considered in evaluating a proposal are its relevance to NASA's objectives, intrinsic merit, and cost.

(2) Evaluation of a proposal's relevance to NASA's objectives includes the consideration of the potential contribution of the effort to NASA's mission.

(3) Evaluation of its intrinsic merit includes the consideration of the following factors of equal importance:

(i) Overall scientific or technical merit of the proposal or unique and innovative methods, approaches, or concepts demonstrated by the proposal.

(ii) Offeror's capabilities, related experience, facilities, techniques, or unique combinations of these which are integral factors for achieving the proposal objectives.

(iii) The qualifications, capabilities, and experience of the proposed principal investigator, team leader, or key personnel critical in achieving the proposal objectives.

(iv) Overall standing among similar proposals and/or evaluation against the state-of-the-art.

(4) Evaluation of the cost of a proposed effort may include the realism and reasonableness of the proposed cost and available funds.

J. Evaluation Techniques. Selection decisions will be made following peer and/or scientific review of the proposals. Several evaluation techniques are regularly used within NASA. In all cases proposals are subject to scientific review by discipline specialists in the area of the proposal. Some proposals are reviewed entirely in-house, others are evaluated by a combination of in-house and selected external reviewers, while yet others are subject to the full external peer review technique (with due regard for conflict-of-interest and protection of proposal information), such as by mail or through assembled panels. The final decisions are made by a NASA selecting official. A proposal which is scientifically and programmatically meritorious, but not selected for award during its initial review, may be included in subsequent reviews unless the proposer requests otherwise.

K. <u>Selection for Award</u>.

(1) When a proposal is not selected for award, the proposer will be notified. NASA will explain generally why the proposal was not selected. Proposers desiring additional information may contact the selecting official who will arrange a debriefing.

(2) When a proposal is selected for award, negotiation and award will be handled by the procurement office in the funding installation. The proposal is used as the basis for negotiation. The contracting officer may request certain business data and may forward a model award instrument and other information pertinent to negotiation.

L. <u>Additional Guidelines Applicable to Foreign Proposals and Proposals Including Foreign Participation.</u>

(1) NASA welcomes proposals from outside the U.S. However, foreign entities are generally not eligible for funding from NASA. Therefore, [unless otherwise noted in the NRA] proposals from foreign entities should not include a cost plan unless the proposal involves collaboration with a U.S. institution, in which case a cost plan for only the participation of the U.S. entity must be included. Proposals from foreign entities and proposals from U.S. entities that include foreign participation must be endorsed by the respective government agency or funding/sponsoring institution in the country from which the foreign entity is proposing. Such endorsement should indicate that the proposal merits careful consideration by NASA, and if the proposal is selected, sufficient funds will be made available to undertake the activity as proposed.

(2) All foreign proposals must be typewritten in English and comply with all other submission requirements stated in the NRA. All foreign proposals will undergo the same evaluation and selection process as those originating in the U.S. All proposals must be received before the established closing date. Those received after the closing date will be treated in accordance with paragraph (g) of this provision. Sponsoring foreign government agencies or funding institutions may, in exceptional situations, forward a proposal without endorsement if endorsement is not possible before the announced closing date. In such cases, the NASA sponsoring office should be advised when a decision on endorsement can be expected.

(3) Successful and unsuccessful foreign entities will be contacted directly by the NASA sponsoring office. Copies of these letters will be sent to the foreign. Should a foreign proposal or a U.S. proposal with foreign participation be selected, NASA's Office of External Relations will arrange with the foreign sponsor for the proposed participation on a no-exchange-of-funds basis, in which NASA and the non-U.S. sponsoring agency or funding institution will each bear the cost of discharging their respective responsibilities.

(4) Depending on the nature and extent of the proposed cooperation, these arrangements may entail:

(i) An exchange of letters between NASA and the foreign sponsor; or

(ii) A formal Agency-to-Agency Memorandum of Understanding (MOU).

M. <u>Cancellation of NRA</u>.. NASA reserves the right to make no awards under this NRA and to cancel this NRA. NASA assumes no liability for canceling the NRA or for anyone's failure to receive actual notice of cancellation.

APPENDIX D
NRA-00-HEDS-02

NASA RESEARCH ANNOUNCEMENT (NRA) SCHEDULE

MICROGRAVITY FUNDAMENTAL PHYSICS: RESEARCH AND FLIGHT EXPERIMENT OPPORTUNITIES

All proposals submitted in response to this Announcement are due on the date and at the address given below by the close of business (4:30 PM EST). NASA reserves the right to consider proposals received after this deadline if such action is judged to be in the interest of the U.S. Government. A complete schedule of the review of the proposals is given below:

NRA Release Date: ....February 15, 2000

Letter of Intent Due: .... March 13, 2000

Proposal Due: .... May 15th, 2000

Submit Proposal to:

Dr. Mark C. Lee
c/o InDyne, Inc.
Subject: NASA Research Proposal (NRA-00-HEDS-02)
300 D Street, S.W., Suite 801
Washington, D.C. 20024
Telephone number for delivery services: (202) 479-2609

Final Selections: ....September, 2000

Funding commences: ....No sooner than October, 2000

(dependent upon actual selection and procurement process)